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(54) Illumination system for ophthalmic lens inspection

Beleuchtungssystem zur Inspektion von Kontaktlinsen

Système d'illumination pour l'inspection des lentilles de contact

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(56) References cited:
EP-A- 0 491 663
US-A- 3 917 391
US-A- 3 985 445

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Description

BACKGROUND OF THE INVENTION

Previously devised systems for the inspection of ophthalmic lenses, especially molded hydrophilic contact lenses, employed human inspection utilizing trays having a rectangular array of wells in which the lenses were submerged in saline solution.

A problem associated with the inspection of ophthalmic lenses is that the lens itself is optically transparent and therefore does not show the usual light and dark features that are found in the inspection of more routine objects.

Heretofore a human inspector viewed each of the lenses under magnification in order to verify that the lens meets each of its required characteristics. In these systems, the tray containing lenses and saline is transferred to an inspection station attended by a human operator. When the tray is placed in the inspection station, a viewing assembly is positioned above a first well. The lens in the well is illuminated from below and an image is transferred by the viewing apparatus and projected upon a screen at the inspector's eye-level. The inspector manually varies the field-of-focus to examine different depths of the lens. A projection system is described in US Patent US-A-3 917 391.

US Patent US-A-39 85 445 describes an apparatus for measuring the frontal power of corneal contact lenses. The apparatus has a well to receive the lens in a cup filled with a liquid in which the material of the lens has a predetermined index of refraction. The apparatus has a sighting optical system and a measuring optical system spaced from each other. The cup is disposed in a gap between the optical systems, the cup bottom having a fluid-tight window.

Current human conducted inspection methods employ the schlieren method of dark field illumination well known in the art, particularly for the study of transparent fluid flow and optical component inspection. In this method, light from a point source is collimated by a lens which then passes through the medium (i.e. lens) under study. The light is then focused by a second lens directly onto a knife edge. Any light deflected by a refractive nonuniformity in the lens (albeit transparent) is not focused at the knife edge. Light thus deflected from interruption by the knife edge is then projected onto a screen by an object lens and a light spot thus occurs on the an otherwise dark projection screen corresponding to the nonuniformity.

After looking for the appropriate lens characteristics and deviations from accepted standards, the human inspector makes a decision as to whether the lens is acceptable. The inspector often finds its useful to move or displace the lens slightly relative to the tray well in which it is contained, or to otherwise disturb the saline solution in order to distinguish between foreign particles in the saline and imperfections in the tray well from characteristics or defects of the lens.

The inspector enters his decision by pushing the appropriate electrical switch to indicate that the lens is either acceptable or to be rejected. The viewing mechanism then indexes over to the next well in the tray where the inspection procedure is repeated. As can be appreciated, certain time constraints must be placed upon the inspector such that if a decision is not made within a predetermined amount of time, the lens is automatically considered defective, and the viewing apparatus indexes to the next well. Likewise, lenses that may otherwise be acceptable but are accompanied by extraneous pieces of foreign material or if two lenses are found in the same well, the situation is considered unacceptable and the contents of the well rejected.

Upon the completion of the inspection of an entire tray of lenses, the inspector activates another electrical switch to initiate disposition of the lenses of the tray just inspected. A disposal unit visits each well of the tray where an unacceptable lens was indicated to suction out and dispose of those lenses. The tray is then transferred along for the packaging of the acceptable lenses.

Although the inspectors are highly trained and are given objective criteria by which to judge the quality and ultimate acceptability of the lenses, one skilled in the art can appreciate that human inspection leaves much to be desired. Human inspectors lack inspector-to-inspector uniformity, and repeatability by a single inspector may be lacking based on the inspector's mental condition and accumulated fatigue. An ophthalmic lens manufacturer, therefore, conservatively rejects many lenses that are acceptable on an objective basis because of limitations in the inspection process.

As the ophthalmic lens industry has grown human inspection has imposed a large manpower and financial burden on the industry and requires a tedious task on the part of the inspector. particularly with regard to contact lenses that are provided for periodic frequent replacement the number of lenses that need to be produced and, therefore, inspected increases dramatically.

To increase uniformity and decrease the number of falsely rejected lenses, an automated inspection system can be implemented where an image of the lens to be inspected is captured using a lamp and a camera and the image then digitized and processed by a computer to make a determination whether the lens is acceptable.

Because of the limited field-of-view of a camera system, and the desire to utilize the field to the maximum extent, it is important that the lens be centered in the field while it is being carried so that lenses are found in a repeatable position from one lens to the next.

A package for ophthalmic lenses having a bowl with a radius of curvature larger than the radius of the lens placed inside the bowl allows the lens to center and settle in the middle of the bowl. When constructed of a nonnucleated polymer, the surface is sufficiently wettable so that when water is placed in the bowl, the water meniscus is substantially flattened in the center and asso-

ciated optical aberrations are thereby eliminated, permitting undistorted in-package inspection.

A more detailed description of the preferred embodiment of the lens package is given in copending European application EP-A-0 604 177 filed concurrently with this application.

The camera of such an automated lens inspection system is operated in an asynchronous fashion using a signal generated by the lens and package moving into the proper location to trigger both the firing of the strobe and subsequent transfer of the image.

Due to the manner in which an image is captured by the camera, a second requirement is that the image be as clear as possible and not blurred by vibration of the lens, the solution in which it is placed, or by motion of the lens package.

A pallet with wells for receiving the containers comprise holes that pass through the pallet. These holes along with a guide and transport system make possible an arrangement of the lamp and camera for capturing an image of a lens that maximizes utilization of the field-of-view of the camera and minimizes blurring.

A high resolution solid state camera such as the Videk MegaPlus® camera made by Kodak of Rochester, New York is employed. This camera comprises a lens fixed on a 14.5 millimeter field-of-view. The camera is fitted with a Nikkor 55 millimeter standard lens set at f/2.8 and attached to an Andover bandpass filter centered at a wavelength of 550 nm with a 10 nm full wave half height (FWHH) to the end of the camera lens. Such a filter removes chromatic aberrations thereby improving overall spatial resolution and maintains a photopic response to the lens inspection similar to a human inspector's ocular response. This filter also removes infrared at the CCD detector which would decrease the overall system modulation transfer function (MTF).

The method of capturing a lens image with a camera and determining whether a lens is acceptable once an image is captured by the camera and reduced to digital data is described in copending European application EP-A-0 604 179 filed concurrently with this application.

A requirement of an illumination system used to inspect transparent objects such as ophthalmic lenses, is to provide a source of light which is sufficiently diffuse so as to not reveal artifacts (details or non-uniformities) of either the lamp itself or of the package containing the lens.

It has been the previous practice to use either a schlieren illumination system as described above, or a projection type system. While a projection type illumination system will sufficiently hide the structure of the light source, the shortcoming in using it with a system for in-package inspection is that the contrast of package details is highlighted. As is readily appreciated, imposing package details on the lens image obtained by the camera would, at a minimum, slow the processing of the digitized image by the inspection algorithm, and possibly cause false rejection of some lenses or even cause the algorithm to fail entirely.

The object of the present invention is, therefore, to provide an illumination system that allows the light produced to pass through the structure of the inspection apparatus, through a lens container pallet to be electronically imaged while the pallet, container and lens are in motion and that is compatible with the operating requirements of the above inspection systems, particularly those of suppressing the details of both the light source and of the package.

More particularly, it is the object of the present invention to provide a strobe illumination system capable of being triggered at the appropriate time by the inspection transport system and producing a flash of light of short duration, but high intensity and uniformity to produce an non-blurred image in the camera adequate to be digitized and mathematically processed.

Both of these objects must be met while permitting the lamp and camera to be positioned to allow the camera to capture a high quality image of the lens. It is preferable that the above objectives be achieved while the lamp and camera are on opposite sides of the lens allowing the light to pass through the lens, an image to be captured by the camera then digitized.

It is a final object of the invention to provide an illumination system that produces consistent illumination from strobe flash to strobe flash, and in particular, consistent illumination over an extended life of the flash tube.

SUMMARY OF THE INVENTION

According to the present invention there is provided an illumination apparatus as defined in the claims. The above objects are achieved by a system for providing diffuse illumination in the inspection of ophthalmic lenses, transparent in nature, for use in conjunction with a computer-based inspection apparatus that analyzes a digitized image of an ophthalmic lens.

Below a package containing an ophthalmic lens in deionized water is an optical diffuser made of flashed opal and below that a light source such as a strobe light. The strobe lamp is capable of firing a 5 Joule, 10 microsecond pulse of light initiated by the image processing system which is in turn triggered by a signal generated by the arrival of a package containing a lens to be inspected. Typically a 450 millisecond recovery time is needed for the strobe to recharge between firings. In the preferrerd embodiment, an arc tube is employed wherein light output diminishes by darkening only in one end of the tube, that end placed outside the reflector.

DESCRIPTION OF THE DRAWINGS

The figure shows the present invention partially in cross-sectional view and partially in a planar elevational view.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the figure, there is shown camera 10 having an x axis (the axis of lens container movement) adjustment knob 12, a y axis adjustment knob 14, and a z axis adjustment knob 16. Adjustment knob 18 provides rotational adjustment in the x,y plane and knob 20 provides rotational adjustment in the y,z plane.

These adjustment knobs are attached to x,y and z axis stages 20, 24 and 26 respectively. Ultimately, these are attached through the x axis stage to the mounting structure 28 through brackets 30.

Camera 10 comprises a lens 32 and bandpass filter 34. The bandpass filter is such as the 550FS10-50 model available from Andover Corporation of Salem, New Hampshire. This filter is centered at a wavelength of 550 nanometers where it transmits 70% of the incident light while transmitting essentially zero energy at wavelengths which are 10 nanometers off the 550 nm center. The functioning of the camera is described in more detail in the above-referenced patent application for the inspection algorithm.

Found below the camera is a transport pallet 36 holding lens containers 38 wherein rest lenses 40. The lenses are substantially surrounded by liquid, preferably deionized water (not shown), in containers 38.

The pallet is transported along a conveyance rail 42, described in more detail in the above referenced patent application describing a lens transport system.

A more detailed description of the preferred embodiment of the lens transport system and pallet system with illumination triggering are given in copending European applications EP-A-0 604 180 and EP-A-0 604 175 (attorney docket VTN-49 and VTN-50) filed concurrently with this application.

As seen in the figure, pallet 36 and conveyance rail 42 contain apertures 44 and 46, respectively.

When pallet 36 is appropriately aligned along the x axis, the center of the pallet aperture 44 and the center of the conveyance rail aperture 46 lie in a common line with the center of the camera lens 32 along an optical axis 48.

Below the conveyance rail is the light source. The strobe lamp is capable of firing a 5 Joule, 10 microsecond pulse of light initiated by the image processing system which is in turn triggered by a signal generated by the arrival of a package containing a lens to be inspected. Typically a 450 millisecond recovery time is needed for the strobe to recharge between firings. The light source is comprised of arc tube 50 surrounded by a flash lamp coil 52.

The conveyance rail aperture 46 is adjustable to different diameters, from substantially closed to open as wide as the pallet aperture 44. Thus conveyance rail aperture 46 located between the diffuser and the lens container, limits the cone angle of the light incident upon the lens container and can be manually adjusted to supply the appropriate amount of light.

Surrounding the light source is a parabolic reflector 54 held in place by a reflector mount 56. The reflector mount in turn is attached to the lamp housing 58. High voltage cables 60 are electrically connected to the flash lamp coil 52 and to the high voltage power supply 62. The high voltage power supply is turned on by a triggering means not shown, but described in the above-referenced patent application describing a pallet for transporting lens containers.

The center of the flash lamp 50, as well as the optical axis of the parabolic reflector 54 is located along optical axis 48.

The parabolic reflector has an opening 64 along the optical axis 48. Above the opening 64 between the flash lamp 50 and the lens container 38 is located a glass plate 66. This glass plate seals the lamp chamber from the external environment, including dust and moisture. Also between the flash lamp and the container undergoing inspection along optical axis 48, is located diffusing glass 68 which acts as an optical diffuser. The diffusion glass is held above the lamp by standoffs 70 and held in place by diffusion holder 72.

The distance between the lamp 50, diffuser 68 and the lens container 38 is made variable by a conventional vertical adjustment mechanism (not shown). These adjustments (along with adjustment of conveyance rail aperture 46) are made to highlight lens contrast while eliminating lens container and lamp structure and energy losses due to the positive optical power of the lens container\deionized water combination.

The strobe flash lamp is available from Perceptics Corporation of Knoxville, Tennessee. As with all lamps, when in use material from the filament or electrodes will vaporize and be deposited elsewhere in the bulb or arc tube. The lamp of the preferred embodiment that is employed is of a design where deposits from vaporization of the electrodes causes the electrode material to be deposited preferentially in one end of the arc tube. According to the preferred embodiment of this invention, such an arc tube is placed with that end receiving the deposits outside the end of the reflector as shown in the figure. The coil is 60 mm long and 25 mm in diameter, with 35 mm of the arc tube outside of the reflector.

Although a portion of the available light is lost outside the reflector, this arrangement has the advantage of producing a consistent light output over a significant part of the lamp's life. Because the lamp first darkens in the bottom portion of the lamp which is outside the reflector, the portion within the reflector that provides the light for this illumination system remains consistent until the darkening reaches into that portion of the lamp in the reflector. It is expected that such a lamp as specified above, arranged according to the invention will function for at least one year at 30 Hz at an output of 5 J (approximately 10^9 flashes) before requiring replacement due to diminished light output.

Claims

1. An illumination apparatus for use with an ophthalmic lens inspection system having wells for receiving one or more ophthalmic lens containers (38), a triggering means responsive to the presence of an ophthalmic lens container (38), a camera (10) with a variable focus lens (32) for capturing an image of the ophthalmic lens (40), means for determining the acceptability of the ophthalmic lens (40) from the camera image indicated by an electric signal, and an ophthalmic lens disposal mechanism connected to receive the signal related to ophthalmic lens (40) acceptability and to separate an acceptable ophthalmic lens (40) from an unacceptable ophthalmic lens (40), said illumination apparatus comprises:

   a strobe lamp (50);
   an electrical power source (62) connected to said lamp (50) and connectable to said triggering means such that, in use, the power source (62) is electrically connected to the lamp (50) when the triggering means responds to the presence of a container (38);
   a reflector (54) surrounding at least a portion of the surface about the lamp (50) and having an opening (64) which, in use, is along the optical axis (48) from the lamp (50) to the camera (10);
   a diffuser (68) which, in use, is located between the lamp (50) and the ophthalmic lens container (38); and
   an aperture (46) which, in use, limits the cone angle of the light incident upon the ophthalmic lens container (38), the aperture (46) being located, in use, between the diffuser (68) and the ophthalmic lens container (38).

2. The apparatus of claim 1, wherein said reflector (54) is a rotatable parabola.

3. The apparatus of claim 1, wherein said strobe lamp (50) is partially outside the reflector (54) located along said optical axis (48), opposite said aperture (46).

4. The apparatus of claim 1, wherein the distance between said diffuser (68), said lamp (50) and said lens container (38) is variable.

5. The apparatus of claim 1, wherein the aperture (46) is variable.

6. The apparatus of claim 1, wherein said strobe lamp (50) has a portion outside the reflector (54), said portion having electrode material deposited on it resulting in darkening of the portion.

7. The illumination apparatus of any of the preceding claims, in combination with an ophthalmic lens inspection system having wells for receiving one or more ophthalmic lens containers (38), a triggering means responsive to the presence of an ophthalmic lens container (38), a camera (10) with a variable focus lens (32) for capturing an image of the ophthalmic lens (40), means for determining the acceptability of the ophthalmic lens (40) from the camera image indicated by an electrical signal, and an ophthalmic lens disposal mechanism connected to receive the signal related to ophthalmic lens (40) acceptability and to separate an acceptable ophthalmic lens (40) from an unacceptable ophthalmic lens (40),

   wherein a volume of liquid substantially surrounds the ophthalmic lens (40) in the ophthalmic lens container (38) and forms an ophthalmic lens (40) having a positive optical power, and wherein
   said camera lens (32) can be varied to compensate for the positive optical power of the liquid in the lens container (38) and to focus the ophthalmic lens image in the camera (10).

Patentansprüche

1. Beleuchtungsvorrichtung für ein Inspektionssystem für ophtalmische Linsen mit Vertiefungen zur Aufnahme von einem oder mehreren Behältern (38) für ophtalmische Linsen, einer Triggereinrichtung, die auf das Vorhandensein eines Behälters (38) für eine ophtalmische Linse anspricht, einer Kamera (10) mit einem Objektiv (32) mit variabler Brennweite zum Aufnehmen einer Abbildung der ophtalmischen Linse (40), einer Einrichtung zum Feststellen der Akzeptabilität der ophtalmischen Linse (40) anhand der Kameraabbildung, die durch ein elektrisches Signal angezeigt wird, und mit einem Mechanismus zum Entfernen von ophtalmischen Linsen, der das Signal aufnimmt, das die Akzeptabilität der ophtalmischen Linse (40) anzeigt und der eine akzeptable ophtalmische Linse (40) von einer nicht akzeptablen ophtalmischen Linse (40) trennt, wobei die Beleuchtungseinrichtung umfaßt

   eine Blitzlampe (50);
   eine elektrische Stromquelle (62), die mit der Lampe (50) verbunden ist und die derart mit der Triggereinrichtung verbindbar ist, daß im Gebrauch die Stromversorgung (62) elektrisch mit der Lampe (50) verbunden wird, wenn die Triggereinrichtung auf das Vorhandensein eines Behälters (38) anspricht;
   einen Reflektor (54), der wenigstens einen Teil der Oberfläche um die Lampe (50) umgibt und der eine Öffnung (64) aufweist, die sich im Ge-

brauch längs der optischen Achse (48) von der Lampe (50) zur Kamera (10) befindet;
einen Diffusor (68), der sich im Gebrauch zwischen der Lampe (50) und dem Behälter (38) für die ophtalmische Linse befindet; und
eine Öffnung (46), die im Gebrauch den Kegelwinkel des auf den Behälter (38) für die ophtalmische Linse einfallenden Lichts begrenzt, wobei sich die Öffnung (46) im Gebrauch zwischen dem Diffusor (68) und dem Behälter (38) für die ophtalmische Linse befindet.

2. Vorrichtung nach Anspruch 1, wobei der Reflektor (54) ein Rotationsparaboloid ist.

3. Vorrichtung nach Anspruch 1, wobei die Blitzlampe (50) längs der optischen Achse (48) gegenüber der Öffnung (46) teilweise außerhalb des Reflektors (54) angeordnet ist.

4. Vorrichtung nach Anspruch 1, wobei der Abstand zwischen dem Diffusor (68), der Lampe (50) und dem Linsenbehälter (38) variabel ist.

5. Vorrichtung nach Anspruch 1, wobei die Öffnung (46) variabel ist.

6. Vorrichtung nach Anspruch 1, wobei sich ein Abschnitt der Blitzlampe (50) außerhalb des Reflektors (54) befindet, wobei sich an diesem Abschnitt Elektrodenmaterial abscheidet, das ein Verdunkeln dieses Abschnittes zur Folge hat.

7. Beleuchtungsvorrichtung nach einem der vorstehenden Ansprüche in Kombination mit einem Inspektionssystem für ophtalmische Linsen mit Vertiefungen zur Aufnahme von einem oder mehreren Behältern (38) für ophtalmische Linsen, einer Triggereinrichtung, die auf das Vorhandensein eines Behälters (38) für eine ophtalmische Linse anspricht, einer Kamera (10) mit einem Objektiv (32) mit variabler Brennweite zum Aufnehmen einer Abbildung der ophtalmischen Linse (40), einer Einrichtung zum Feststellen der Akzeptabilität der ophtalmischen Linse (40) anhand der Kameraabbildung, die durch ein elektrisches Signal angezeigt wird, und mit einem Mechanismus zum Entfernen von ophtalmischen Linsen, der das Signal aufnimmt, das die Akzeptabilität der ophtalmischen Linse (40) anzeigt und der eine akzeptable ophtalmische Linse (40) von einer nicht akzeptablen ophtalmischen Linse (40) trennt,

wobei ein Flüssigkeitsvolumen im wesentlichen die ophtalmische Linse (40) im Behälter (38) für die ophtalmische Linse umgibt und eine ophtalmische Linse (40) bildet, die eine positive optische Brechkraft hat, und wobei das Kameraobjektiv (32) so eingestellt werden kann, daß die positive optische Brechkraft der Flüssigkeit im Linsenbehälter (38) kompensiert wird und das Abbild der ophtalmischen Linse in der Kamera (10) fokussiert ist.

Revendications

1. Appareil d'éclairement pour emploi avec un système d'inspection d'une lentille ophtalmique présentant des puits pour recevoir un ou plusieurs récipients (38) pour lentille ophtalmique, un moyen de déclenchement sensible à la présence d'un récipient (38) pour lentille ophtalmique, une caméra (10) avec un objectif (32) à distance focale variable pour capter une image de la lentille ophtalmique (40), des moyens pour déterminer si la lentille ophtalmique (40) est acceptable à partir de l'image de la caméra, ce qu'indique un signal électrique, et un mécanisme de mise au rebut d'une lentille ophtalmique relié pour recevoir le signal relatif au fait qu'une lentille ophtalmique (40) soit acceptable et pour séparer une lentille ophtalmique (40) acceptable d'avec une lentille ophtalmique (40) non acceptable, ledit appareil d'éclairement comporte:

une lampe stroboscopique (50);
une source de puissance électrique (62) reliée à la dite lampe (50) et pouvant se relier audit moyen de déclenchement de façon qu'en service la source de puissance (62) soit électriquement reliée à la lampe (50) lorsque le moyen de déclenchement répond à la présence d'un récipient (38);
un réflecteur (54) entourant au moins une portion de la surface autour de la lampe (50) et présentant une ouverture (64) qui, en service, se trouve le long de l'axe optique (48) allant de la lampe (50) à la caméra (10);
un diffuseur (68) qui, en service, est situé entre la lampe (50) et le récipient (38) pour lentille ophtalmique; et
une ouverture (46) qui, en service, limite l'angle de cône de la lumière tombant sur le récipient (38) pour lentille ophtalmique, l'ouverture (46) étant, en service, située entre le diffuseur (38) et le récipient (38) pour lentille ophtalmique.

2. L'appareil de la revendication 1, dans lequel ledit réflecteur (54) est un paraboloïde de révolution.

3. L'appareil de la revendication 1, dans lequel ladite lampe stroboscopique (50) est, partiellement à l'extérieur du réflecteur (54), située le long dudit axe optique (48), en face de ladite ouverture (46).

4. L'appareil de la revendication 1, dans lequel la dis-

tance entre ledit diffuseur (68), ladite lampe (50) et ledit récipient (38) pour lentille est variable.

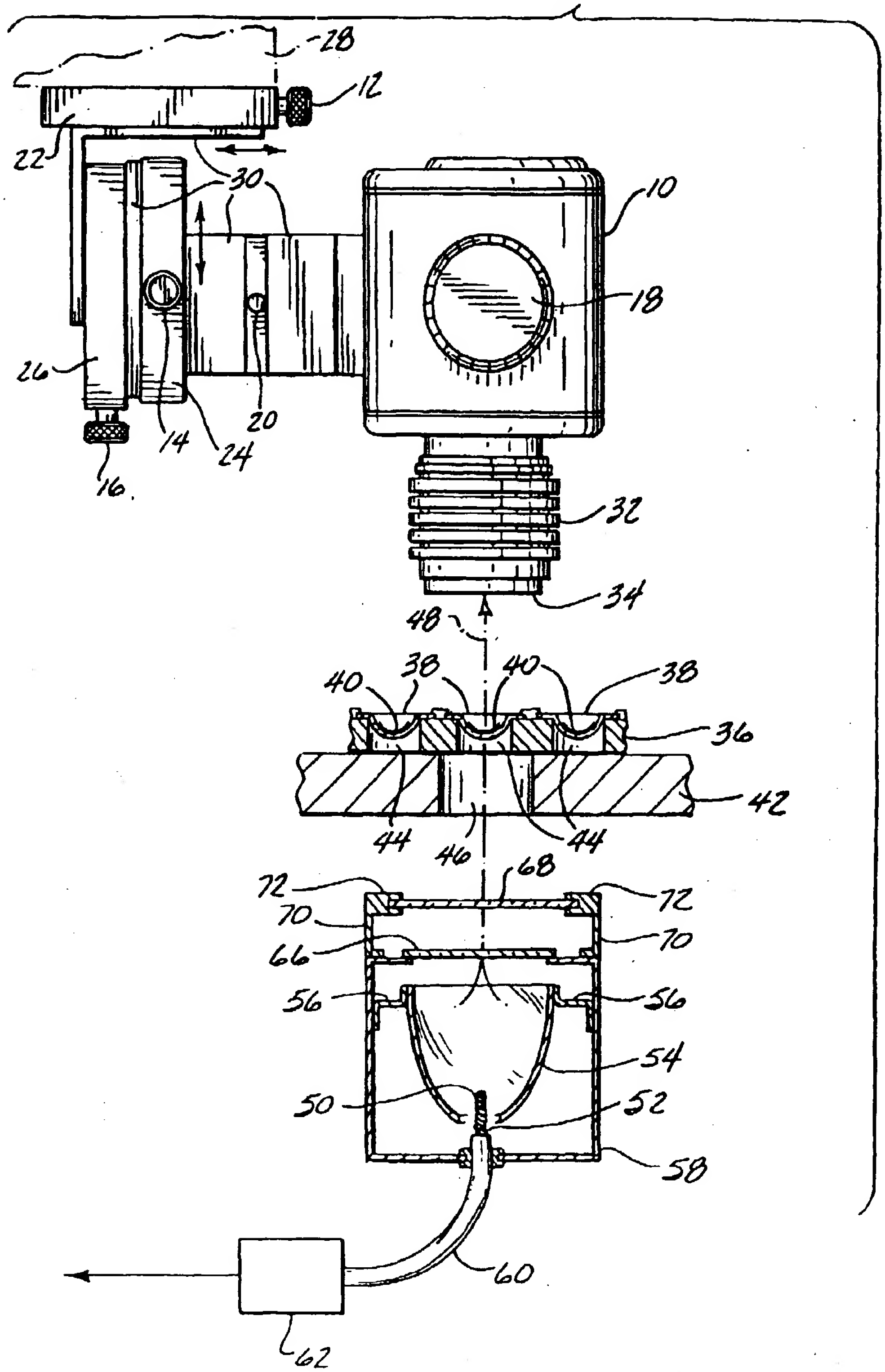
5. L'appareil de la revendication 1, dans lequel l'ouverture (46) est variable.

6. L'appareil de la revendication 1, dans lequel ladite lampe wstroboscopique (50) a une portion à l'extérieur du réflecteur (54), ladite portion présentant du matériau d'électrode qui se dépose sur elle et se traduit par un obscurcissement de la portion.

7. Appareil d'éclairement de l'une quelconque des revendications précédentes, en combinaison avec un système d'inspection d'une lentille ophtalmique présentant des puits pour recevoir un ou plusieurs récipients (38) pour lentille ophtalmique, un moyen de déclenchement sensible à la présence d'un récipient (38) pour lentille ophtalmique, une caméra (10) avec un objectif (32) à distance focale variable pour capter une image de la lentille ophtalmique (40), des moyens pour déterminer si la lentille ophtalmique (40) est acceptable à partir de l'image de la caméra, ce qu'indique un signal électrique, et un mécanisme de mise au rebut d'une lentille ophtalmique relié pour recevoir le signal relatif au fait qu'une lentille ophtalmique (40) soit acceptable et pour séparer une lentille ophtalmique (40) acceptable d'avec une lentille ophtalmique (40) non acceptable, dans lequel

   un volume d'un liquide entoure substantiellement la lentille ophtalmique (40) contenu dans le récipient (38) pour lentille ophtalmique et forme une lentille ophtalmique (40) présentant une vergence optique positive, et dans lequel on peut faire varier ledit objectif (32) de la caméra pour compenser la vergence optique positive du liquide dans le récipient (38) pour lentille et pour focaliser l'image de la lentille ophtalmique dans la caméra (10).

FIG-1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